FleXO™: Bridging the Cost/Performance Gap in the Oscillator Market

Cypress Semiconductor White Paper

By Chris Martin
Senior Applications Engineer
Timing Solutions

Executive Summary

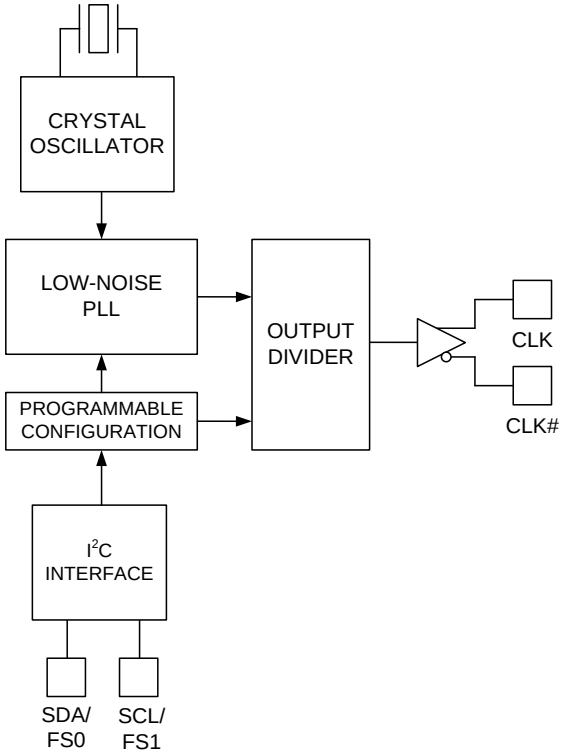
This paper compares Cypress' FleXO oscillator with the other main types of oscillators. It discusses the advantages, disadvantages, and typical applications of each type.

FleXO offers several key benefits over other common types of timing solutions. FleXO's primarily targets telecommunications and networking applications. It provides superior flexibility, cost, and lead time compared to alternative solutions while still offering excellent frequency stability and low phase noise, giving the customer an ideal balance of performance, cost, and flexibility.

What is FleXO™?

FleXO is a high-performance PLL-based programmable crystal oscillator offered by Cypress. The name is an amalgam of the word 'Flexible' – due to the device's programmability – and 'XO', industry shorthand for crystal oscillator. By integrating a quartz crystal with a high-performance programmable PLL and various output buffer type options, FleXO can meet timing needs from 50 MHz to 690 MHz while coupling low phase noise (0.6 ps typical RMS jitter from 12 kHz to 20 MHz offset) with the superior frequency stability of a quartz crystal-based solution. FleXO is targeted toward high-end timing applications such as telecommunications and networking products, where high-frequency crystal oscillator (XO) and surface acoustic wave (SAW) oscillator (SO) solutions also compete. FleXO is available in an industry standard 5.0-mm x 3.2-mm ceramic LCC package and can operate at 2.5 V or 3.3 V, with an option for an LVDS, LVPECL, or LVCMOS output. FleXO also has options for in-system frequency selection via input select pins or I^2C, allowing the user to test system timing margins or use a single device across multiple platforms. The example block diagram in Figure 1 outlines the basic functional blocks of FleXO.

Figure 1. Sample Block Diagram for FleXO with I^2C/Frequency Select Interface



Where FleXO Fits In

To evaluate FleXO against the existing oscillator solutions, various characteristics are compared in Table 1. For a more detailed comparison of the types of oscillators, see the Appendix on page 5. Table 1 shows that FleXO offers a lower cost alternative to SAW oscillators (below 690 MHz) and also competes with traditional XOs in the 50 MHz to 200 MHz range. FleXO typically does not compete in the lower end of the performance spectrum where cheaper traditional XOs and PLL-based XOs dominate.

Clearly, the “sweet spot” for FleXO lies above the frequency limit of XOs (~200 MHz max) up through its own maximum frequency of 690 MHz. In this range, the performance offered by FleXO is often sufficient to meet application requirements, while the price—when compared to that of an SO—is very attractive. FleXO is also a good option below 200 MHz when the cost of an XO starts to become prohibitive (typically above 50 MHz or so), particularly for less commonly used frequencies.

Table 1. Relative Characteristics of the Different Oscillator Types

	Oscillator Type			
Parameter	**XO**	**PLL-based XO**	**SO**	**FleXO**
Typical Output Frequency Range	10 kHz to 200 MHz	1 MHz to 200 MHz	50 MHz to 2 GHz	50 MHz to 690 MHz
Typical RMS Phase Jitter (12 kHz to 20 MHz)	0.2 ps	N/A[1]	0.3 ps	0.6 ps
Typical Frequency Stability vs Temp (Does not including initial accuracy or aging)	±20 ppm	±20 ppm	±100 ppm	±20 ppm
Configuration Flexibility	Low	High	Low	High
Custom Order Sample Lead Time	Long (> 10 weeks)	Short (< 1 week)	Long (> 10 weeks)	Short (< 1 week)
Solution Cost (1k units)[2]	< $2 (< 50 MHz) $2 - $20 (> 50 MHz)	< $3	$20 - $30	$3 - $5

Note 1: Phase jitter is not a relevant specification for these devices. Performance is usually specified in period or cycle-to-cycle jitter.
Note 2: All price ranges based on data accumulated from a major distributor website for various frequencies and minimum 1kU purchase quantity.

XOs, SOs, and FleXO all contend for the same telecom/networking sockets. So, it is important to consider your priorities when selecting which kind of oscillator is best for a particular application. Ask the following questions during evaluation:

Is speed to samples important?

What are the jitter/phase noise requirements of the system?

What is the maximum tolerable frequency variation?

Is the solution cost a priority?

When these questions are answered, it becomes clear as to which oscillator type offers the most benefits. For FleXO and similar products, one of the disadvantages when compared to SAW oscillators is a narrower range of output frequencies – limited to 690 MHz maximum. The other disadvantage is a potentially worse phase noise performance, although the difference in practical applications is often marginal. Thus, if FleXO can meet the frequency and phase noise requirements of a design, it holds several advantages over an SO in all other important areas, making it the best option. And because it comes in an industry standard 5.0-mm x 3.2-mm LCC package and pinout, FleXO can be used as a drop-in replacement in designs using an XO or SO, thereby reducing system cost.

FleXO is designed specifically to meet the most common performance requirements in networking and telecom applications. Figure 2 on page 3 shows an example of FleXO performance versus a standard XO and an SO, while Figure 3 compares the frequency stability over temperature of FleXO versus an SO. As shown in Figure 2, while the performance cannot match that of an XO or SO, FleXO can often meet application requirements (for example, < 1 ps RMS jitter from 12 kHz to 20 MHz offset) with sufficient margin for the designer despite the small sacrifice of additional phase noise. Figure 3 shows the frequency stability advantage FleXO holds over the typical SO. The frequency drift over temperature is far less than that of an SO, preventing the designer from losing valuable ppm error timing margin.

Figure 2. Comparison of Phase Noise Performance at 152.52 MHz, FleXO vs XO vs SO

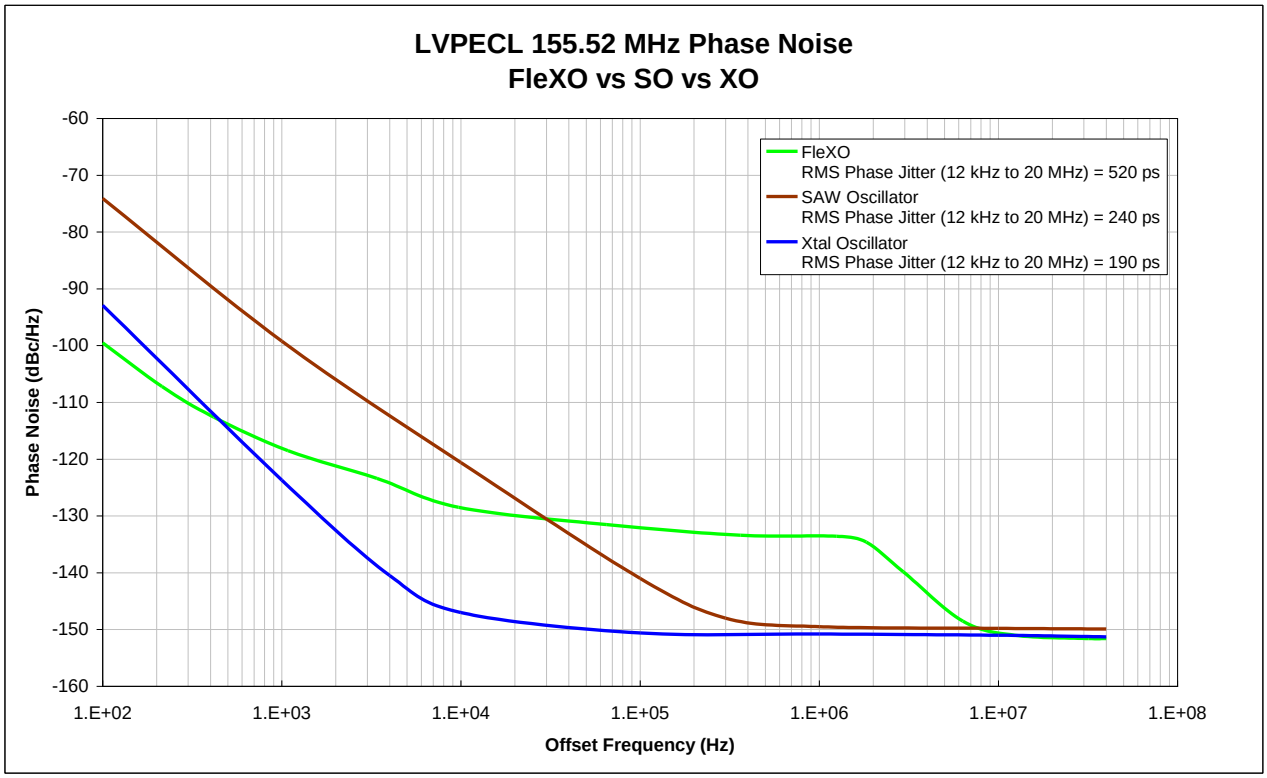
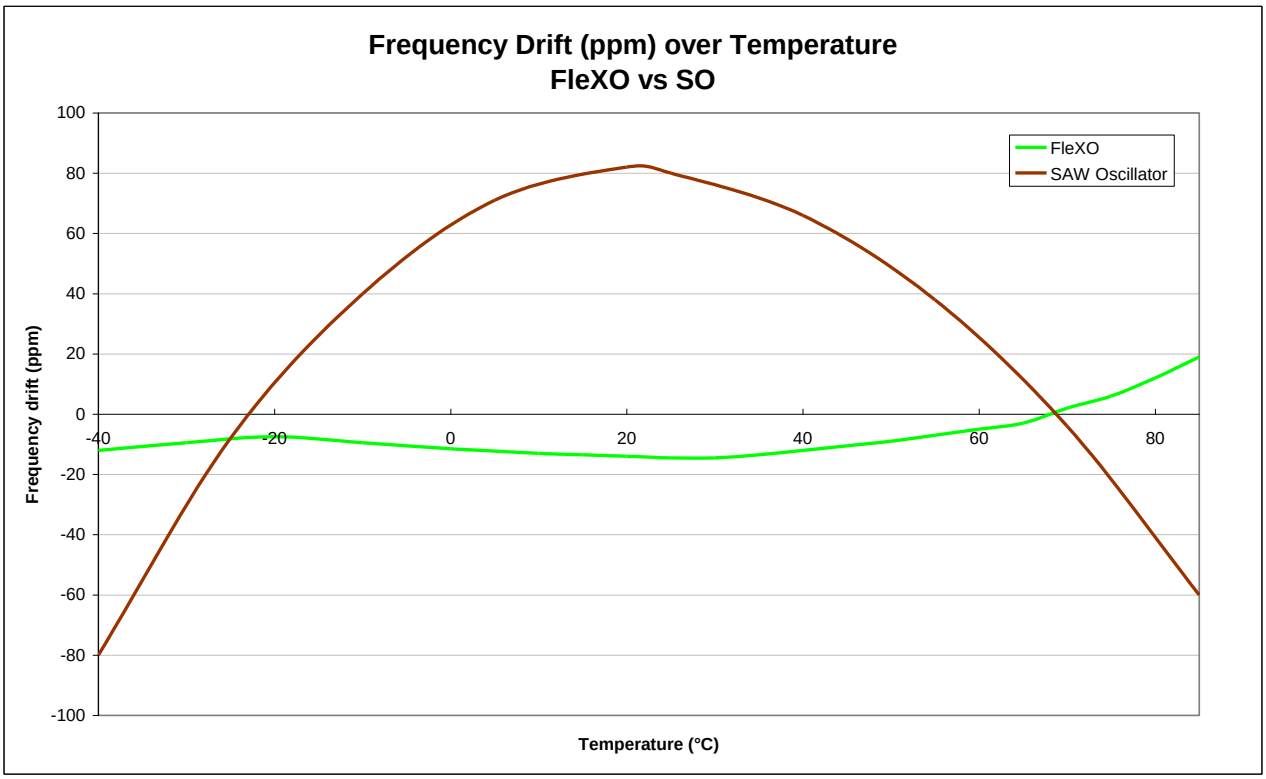


Figure 3. Frequency Stability over Temperature, FleXO vs SO



As a case study, consider the design of a 10-Gigabit Ethernet switch. The system engineer is considering using either a 156.25 MHz or 312.5 MHz clock, and requires less than 1.5 ps RMS phase jitter over the 1.875 MHz to 20 MHz offset range for either output frequency. He is also interested in testing system margin by varying the frequency. A SAW oscillator meets his performance requirements, but does not allow him to change the output frequency easily. Here is where FleXO can offer great value. Not only can Flexo offer sufficient performance—RMS phase noise of 0.3 ps (typical) for both output frequencies—but it can solve the issue of having multiple output frequencies from a single device. Configurations for both 156.25 MHz and 312.5 MHz can be programmed into FleXO. The engineer can choose between them using I^2C or frequency select pins, allowing either frequency to be used in production, or a single device to be used across multiple platforms. Additionally, I^2C can be used to shift in more output frequency configurations, making system frequency margin testing possible. These benefits come at a significantly lower cost than the alternative solution of an SO, making FleXO the obvious choice in this 10-Gigabit Ethernet switch design.

Common Applications and Frequencies for FleXO

Here is a sample list of frequencies and applications for which FleXO can provide a cost-effective alternative to XO and SO solutions:

100.00 MHz – PCI, SATA, SAS
106.25 MHz – Fibre Channel 1, 2
122.88 MHz – Wireless
125.00 MHz – Gigabit Ethernet, PCI, Infiniband
132.8125 MHz – Fibre Channel, Wireless
153.60 MHz – Wireless
155.52 MHz – SONET
156.25 MHz – 10 Gigabit Ethernet XAUI
159.375 MHz – 10 Gigabit Fibre Channel XAUI
212.50 MHz – 4 and 8 Gigabit Fibre Channel, FCoE
311.04 MHz – SONET
312.50 MHz – 10 Gigabit Ethernet XAUI
622.80 MHz – SONET OC192

All of these frequencies are supported by FleXO and have pre-configured factory devices available for sampling or order. Typical phase jitter specifications for these frequencies and applications are all below 1 ps RMS, providing sufficient performance for most designs.

Summary

Cypress's FleXO high-performance PLL-based solution is gaining popularity in networking and telecom applications because of its lower cost. It also combines the benefit of a quartz oscillator (frequency stability) with the advantages of a programmable PLL-based oscillator (quick sampling, flexible configuration), and still offers phase noise and jitter that is often comparable to that of XOs and SOs. FleXO also offers additional features such as frequency select and frequency margining, allowing the designer to use multiple output frequencies or check the system timing margin quickly and easily. The combination of features, performance, and cost make FleXO the best value in the high performance oscillator marketplace.

Appendix

Different Types of Oscillators

To determine where FleXO fits in the overall timing market, a comparison between the various types of oscillators is helpful. This appendix reviews and compares the features of the standard crystal oscillator (XO), the PLL-based XO, the SAW oscillator (SO), and FleXO.

Standard XO

The quartz-based oscillator has long been the solution of choice for a majority of timing needs due to the combination of performance (low jitter and phase noise), temperature stability (without compensation), and cost. A standard XO consists of a crystal blank suspended in a hermetically sealed package coupled with a silicon-based oscillator circuit and operates in a bulk acoustic wave (BAW) mode. XOs dominate the low and mid-range markets for frequencies below 50 MHz. While common frequencies are readily available and benefit from economies of scale to allow low costs, generating nonstandard frequencies can be not only costly, but can also include long lead times due to the complicated manufacturing process for custom crystal frequencies. Additionally, frequencies above 50 MHz usually require overtone operation, adding crystal manufacturing requirements as well as additional circuitry, increasing the cost significantly as the desired output frequency rises. Some newer manufacturing processes may allow fundamental mode operation beyond 200 MHz but the cost is an issue in such cases.

PLL-based XO

To reduce cost and cycle time, many XO vendors have taken the silicon oscillator circuit and added a programmable PLL to the IC. This allows the vendor to select a mature, low cost, easily manufactured crystal frequency and use the programmable PLL to create a wide range of output frequencies from the single crystal reference frequency. Typically, these programmable oscillators range from 1 MHz to 200 MHz. The frequency stability matches that of a standard XO because the PLL receives its reference signal from the quartz oscillator circuit output. However, relative to standard XOs, the programmable PLL XOs have high phase noise and jitter. This poor jitter performance limits them to low and mid-range applications such as consumer electronics. The main advantages of this type of oscillator are lower cost (at frequencies greater than 50 MHz) and shorter lead times.

SAW Oscillator

Surface acoustic wave (SAW) oscillators, as the name implies, have a different mode of operation from the BAW-based XOs. An SO still relies on piezoelectric material for its resonator, but in addition to quartz, lithium tantalite or lithium niobate can be selected, depending on the application. SOs offer higher performance in terms of output frequency (up to 2 GHz) and excellent phase noise, but whereas a BAW quartz oscillator has a relatively flat, cubic order temperature stability characteristc, a SAW oscillator suffers from a quadratic order temperature stability characteristic (see Figure 3). Even when temperature compensation circuitry is included, an SO typically cannot match the temperature stability of an XO. Additionally, the cost of an SO is higher than that of an XO (mainly due to high frequency performance rather than manufacturing cost), although for the more common frequencies in the range of overlap (100 MHz to 200 MHz), SO pricing may occasionally be competitive with that of XOs. Lead times for nonstandard frequencies are long, comparable to the lead times for custom XOs.

FLeXO (High Performance PLL-based XO)

As the newest entry to the oscillator market, FleXO fills the gap between regular PLL-based XOs and SOs, maintaining the advantages of the former (low cost, short cycle times, good temperature stability) while offering performance competitive with the latter (output frequencies up to 690 MHz, typical RMS phase jitter of 0.6 ps). Specifically, these oscillators target the networking and telecommunications market, where their performance is more than sufficient for most applications and their cost advantage and flexibility compared to SAW oscillators makes them an attractive alternative. High-performance PLL-based XOs, such as FleXO, are currently used in a variety of applications including 10 Gigabit Ethernet, SONET, PCI Express, Fibre Channel, ADSL, and high-end consumer electronics (for example, set top boxes).

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone: 408-943-2600
Fax: 408-943-4730
http://www.cypress.com